Commercial Dehydration: A Factor in the Solution of the International Food Problem

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THE world war through which we have just passed has awakened us to the importance of the theories of Malthus, long since expressed. In days of peace, with new countries opening up and extending their agriculture, new and improved methods of food handling and transportation we were inclined to regard the dangers of food shortage or starvation as imaginary and impossible, and to believe that our system of crop production and marketing, while not fully utilizing the scientific knowledge available, were at least sufficient to safeguard us from hunger or serious economic disturbance. Now the awakening has come, and we appreciate more fully than ever before the perils which may threaten through waste, unscientific methods and an improperly coördinated regulation of supply and demand.

The four and one-half years through which we have just passed have, because of the war, caused us to study deeply the problems of food supply and food control. It has fallen to this country to be the storehouse from which enormous supplies of foods have been withdrawn for the use of the fighting forces and the civilian population of Europe. This demand upon our resources has been very largely for cereals and especially for wheat. Because of the necessity for sending enormous quantities of breadstuffs to the Allies, the conservation of food supplies has been studied with particular acuteness, and these studies have had their fruition in the movement for war gardens and for more careful preservation by canning, and particularly in the stimulation of drying as a means of protecting foods against spoilage and preserving them for future use.

Dehydration, dessication, or drying as applied to foods may be defined as the process of removal of surplus water without destruction of the cellular tissues, or impairment of the energy values. Since practically all foods except the ripe seeds of cereals, legumes,

and a few other food plants contain a large percentage of water and as a result are of relatively short keeping quality unless conserved by special means, it follows that the rapid, regulated evaporation or drying of such foods will add greatly to the world's stock and in a form which is capable of easy storage, favorable transportation and universal employment.

DEHYDRATION AN OLD PROCESS

Dehydration is not a new art for drying has been known for hundreds of years and is probably the oldest method of food preservation which the human race has employed. In our own country it was used in the early colonial days for both vegetable and animal foods. Massachusetts colonists dried corn after it had been cooked, the product being known as samp. As soon as fruits were produced, these, and especially the apple, were also dried in considerable quantities. Along the coast the drying of fish became an important industry, and throughout New England to the present time will be found the application of this process of food preservation as a sort of local or primitive industry. In other parts of the country other vegetables and fruits and meat products were dried. Peas and sweet corn may be mentioned as examples of the former, while along the Pacific coast the long sunny period lends itself particularly to the drying of prunes, raisins, and other fruits. In the arid regions of the interior the Indians, and later the early settlers, dried their beef or buffalo meat by cutting it into thin strips and hanging them up for the sun and wind to remove the excess moisture and sear over the outside with a protective coating which would prevent infection and spoilage. This was known as jerked beef. Thus, long before the advent of canning on an extensive scale, the process of drying had been utilized in this country. In other countries it had doubtless been used for hundreds of years.

Dried fruits have been used in America for many years and have become an important part of our food products. On the other hand, dried vegetables have, until recently, been prepared only on a small or domestic scale, probably owing to the plentiful supply of fresh materials. The movement due to the necessity for increased conservation of foods has stimulated experiments along this line, especially during the past two years, with the

result that many foods formerly never kept in the dried condition are now suggested for domestic use, as articles of commerce on a large scale, and as items in the food supply of our Army and Navy, in the large camps and for overseas shipment to our own troops and to our Allies. The preparation of these so-called "dehydrated" foods is now being planned extensively by numerous manufacturers, and a great increase in output for the present year is suggested.

That this is not a really new and untried form of subsistence is evident when we recall that such foods have been used by explorers, in the tropics, in our own armies, and in the armies of other nations. During the Civil War dessicated products were used quite extensively especially as a means of combating scurvy among the troops, and numerous reports of medical officers mention the use of concentrated soup, dessicated vegetables and dried apples and peaches as additions to the regular ration issued as a safeguard to the health of the men. During the Boer War these foods were supplied to the troops in considerable quantity with good results. At the outbreak of the present war large orders were placed by the British authorities, and these foods have been constantly supplied to them. Millions of pounds of dried potato and other vegetables, and of mixtures of vegetables to be used for preparation of soups and stews have been sent across the Atlantic from Canada and the United States.

While vegetables and fruits of all kinds may be prepared in dehydrated form, this report deals chiefly with those products which appear most available as army supplies, as potatoes, turnips, cabbage, onions, carrots, tomatoes, beets, and spinach, and the soup mixture commonly spoken of as "Julienne."

DRYING OVERSHADOWED BY CANNING

Approximately 100 years ago a new method of food preservation was introduced into America. This was the process of hermetically sealing in air-tight containers and subjecting to heat. It was brought to America from England, where it had been practiced for about fifteen years. The first patent on the preservation of food in air-tight containers was granted about 1806 to an Englishman, Saddington, and another in 1810 to a Frenchman, Appert, who independently discovered the method and utilized

it in France. This process was brought to America by William Underwood, who, after tramping over the whole eastern section of the United States, finally settled in Boston and established a company for preserving foods by his process.

The process of canning was at once seen to be so simple and so applicable to many kinds of food materials that it apparently completely overshadowed the simpler process of drying. This was especially the case after the introduction of tinned "cans." Furthermore, canned foods could be transported into any climate, be left exposed to the action of sun or rain, and so long as the container was intact, the food, if perfectly sterilized, was properly conserved. The Civil War with its great requirements of preserved foods for the armies gave a big impetus to the business, and later improvements in the methods of sterilization and in can-making greatly increased its scope until we have the enormous industry of today.

While this has been going on, there has been also a tremendous development in the preservation of foods by cold storage and by other physical means, such as pasteurization, salting, etc. With all the expansion along these lines, drying was practically forgotten, except on a domestic scale and in the dry valleys of the Pacific slope, where the fruits could be preserved very conveniently by this method by action of the sun.

The drying of potatoes and other vegetables on a semi-commercial scale was first done apparently by A. F. Spawn, an American resident in Australia in 1886, but the industry did not make a business success.

At the time of the discovery of gold in the Klondike, the rush of miners to that district created a demand for foods which were light and could be easily transported, and dried potatoes imported from Germany were sold the miners in considerable quantity. These were restored for use by soaking in water and could be served in the form of hashed or fried potatoes, and while they were not extremely palatable, they did supply a quickly prepared and energy-giving ration for the hard-working miner.

Noting the success of the German product, some attempts were made to manufacture dried potatoes in Oregon and Washington, but these were far from successful at first, because the manufacturers used sulphur as a means of preventing the darken-

ing of the slices of potatoes before drying, the amount of sulphur being entirely too great, with the result that the taste of the potato and the odor when cooking was very objectionable. This, however, was shortly overcome, and dried potatoes were manufactured in this country, though even this was far from modern dehydration.

When we speak of "modern" dehydration we mean foods which either with or without previous treatment have been subjected to the action of carefully regulated currents of air in which the temperature and humidity are both properly controlled, a process which results in the food product gradually losing water, but without giving up its color or flavor or having its cellular structure impaired. The modern dehydrated product, therefore, will reabsorb water, swelling to its normal size and appearance, and, when cooked, will have essentially the flavor, appearance, and odor of freshly cooked material made from the fresh vegetables. The early products were far from meeting these requirements, and the same is true of many made at the present time. When the White Fleet went on its famous voyage around the world, a large quantity of dehydrated vegetables was purchased for the use of the fleet. These were so objectionable as a result of improper methods of dehydration, which had produced blackening and scorching, that they were practically uneatable and hundreds of pounds were thrown overboard. Not only was there a considerable loss at that time, but there was also created in the minds of the officers of the Navy a strong prejudice against any foods prepared by this method, a prejudice which has existed until the present day. However, progress was bound to come, and the best dehydrated products of the present day will meet every requirement which it is desired to impose upon them as regards appearance, flavor, and quality.

THE DRYING INDUSTRY STIMULATED BY WAR

War seems to be a great stimulator of methods of food preservation. Just as the Civil War stimulated the canning industry, so the Boer War, and, to a great extent, the European War, stimulated the drying industry. During the Boer War the British Army in South Africa was supplied with thousands of pounds of dried vegetables mixed so as to form the basis for a nutritious and quickly prepared soup. Much of this material

was manufactured in Canada and shipped from Canadian or American points to South Africa. With the closing of the war, one of the manufacturers was left with several thousand pounds of such a soup mixture for which there was no local sale in the domestic markets, possibly owing to the fact that the average consumer much preferred to buy vegetables in the fresh state, and possibly because the mixture was not ideal from the standpoint of flavor and palatability. However, this material was not thrown away, but was put up in barrels which were carefully paraffined and stored away. After the outbreak of the European War in 1914, they were sent to the British Army and utilized in the preparation of soups just as the bulk of the lot had been used fifteen years before. I cite this as an example of the keeping quality of dehydrated products, provided storage conditions are satisfactory, and that moisture and insect pests are prevented from gaining access to the food substances.

BEGINNING OF THE DRYING INDUSTRY IN THE UNITED STATES

By 1910, a number of small factories had begun to manufacture the dehydrated vegetables and soup mixture in the United States. They had not proved highly satisfactory from the commercial standpoint. However, the soundness of the fundamental principle was recognized, and improvement was then merely a matter of applying scientific methods and perfecting details. With the outbreak of the world war came a demand for more of these products for the armies abroad, and thousands of tons were sent. With our own entrance into the war came the question of supplying these materials to our own forces. At first there was merely no objection. Then came a willingness to purchase a small amount as an emergency supply of food materials, and finally, during the past year, there has been a demand for large quantities of these dried vegetables to take the place of the fresh ones which could not be obtained in sufficient quantity in England and France. The result is that during the past twelve months many thousand tons of dried vegetables and soup mixtures have been purchased for the use of the American armies.

Let us see how our opponents in the war have taken advantage of this process. In 1898 there were in Germany only three small drying plants with an output large enough to be worth mention-

ing. This method of preservation may be regarded as apparently successful, for in 1906 the number of plants in operation had increased to 39, in 1909 to 199, in 1914 to 488, and in 1916 to 841. In addition to this, 2,000 breweries were utilizing some portion of their equipment in the drying of food materials. It is stated that in 1917 about 1,900 plants were in operation, or under construction, and the total quantity of potatoes alone dried in Germany was more than three times the total crop of the United States. These facts will explain one of the reasons why Germany was able to maintain her food supplies during the war. The German product was not as good as the best American product of today, and we have little reason to doubt, therefore, that if insistence is laid upon the high quality of the raw material and the use only of the best methods, the dehydrated vegetables industry in the United States will develop at a rapid rate and become a powerful factor in the conservation movement and in the stabilization of agricultural crops.

Dehydrating Systems in the United States

There are now in this country probably twenty-five small plants operating on dehydrated vegetables. Several methods are in use, but in all the fundamental intent is the same, namely, to remove the excess of water so as to obtain a product which will keep for a long period of time, which will not undergo spoilage as a result of microbic action or other form of chemical change, and which will conserve the food value of the materials intact. The basic principle of dehydration is extremely simple, since it implies only the removal of the water contained in and between the cells of the food substance, with the result that the stored food materials, salts, etc., are concentrated in direct ratio to the water evaporated.

Since only replaceable water is taken away, it follows that the nutritional value of the food has not been depreciated. Moreover, if the process is applied while the vegetables and fruits are still in a state of absolute freshness, the special flavor-giving compounds are apparently conserved intact, hence the "fresh" flavor which is characteristic of the best products made by this method. For the finest grades of dried products the rate of evaporation should be such as to bring about the dehydration of the cell-contents without rupture of the cell walls.

By this means the weight of the food is reduced from 80 per cent to 90 per cent, depending on its character, and the bulk is in general diminished to one-fourth or one-sixth of the original volume. By a suitable process of compression the nearly dried material may be brought to a very compact form. Not all the water is driven off, there remaining generally from 7 to 12 or even 15 per cent. It is an advantage to secure quite thorough drying, and in general the water content of dehydrated vegetables should not exceed 10 per cent by weight. Complete removal makes the absorption of water in preparation for cooking extremely slow, while too high a percentage increases weight unduly and also renders the foods more subject to slow deterioration, due to action of moulds, bacteria or intracellular changes, or to slow oxidative changes.

The method of preparation affects in some measure the quality of the product. If the drying is begun at too high a temperature or goes on too rapidly, certain physical or chemical changes seem to take place in some kinds of vegetables whereby the water-absorbing power is impaired. If the initial temperature applied to the fresh (wet) material is too high, a process analogous to scalding or scorching results in some instances. In drying vegetables, therefore, the proper principle seems to be to subject the fresh material to air of relatively low temperature (100 to 120 degrees) and relatively high humidity, and to bring it gradually to a high temperature and low humidity. The specifications for dehydrated foods might well be so drawn as to require the applications of this procedure. The methods now in use may be classified as follows:

1. *Tunnel Systems.* These, as the name would imply, consist of long chambers or tunnels into which the prepared vegetables are introduced on screens or racks and through which a strong current of dry air is blown. There are a number of slight modifications in the arrangements of the screens and in the method of heating and driving the air, but in the majority of cases the heat is supplied by extensive coils of steam pipe, and the air is forced through by means of powerful fans. In some instances the racks holding the vegetables are placed on trucks which run on tracks, so that the material is introduced at one end and delivered in dry form from the other end. In other cases the tunnels have side entrances

and the trays are inserted and removed by hand. The weak point of the tunnel system lies in the fact that there is not absolute control of the physical conditions and as a result many vegetables, especially potatoes, are likely to be overheated and scorched, and more or less broken down in their cellular structure.

2. *Kilns.* The second type of plant may be described as kilns. These are based on the construction of the hop kiln as employed in California and Oregon and to some extent in New York State for the drying of hops and the evaporation of apples. They consist essentially of square chambers with sloping roofs and perforated floors, heated from below by means of stoves or furnaces. The vegetables to be dried are spread on the floor to a depth of four to six inches and the hot air from the stove passes up through the layer, taking away the moisture, which is conducted from the chamber through a ventilator in the roof. The material on the floor must be stirred up, or turned over, from time to time, and this is ordinarily accomplished by men with shovels. The products of the kilns are rather varied in character. Some are quite satisfactory, while on the other hand, others are very much overheated, or may go to the other extreme and be underdried. A lack of uniformity is therefore likely to be found in products of this method.

3. *Vacuum Process.* A third type is the vacuum process, which consists of closed chambers with large numbers of shelves heated by steam and with a greatly reduced atmospheric pressure. By the constant application of the vacuum to the process the water vapor is removed and the material dehydrated. This process gives excellent results for many kinds of products, but is rather severe and tends to break down the cellular structure.

4. *Special Machines.* Special types of chambers or machines have been invented and are now in use in a number of places, the air passing through the chamber being conditioned so as to bring about a carefully regulated drying. Other special types of machines force the rapidity of drying, but have not the careful regulation which seems to be essential in the preparation of the finest products. As a result, therefore, it may be stated that only in those processes where we have the practically perfect control of temperature, humidity, and rate of air flow do we get products which will retain their color, appearance, and flavor,

and when soaked in water will return to approximately the normal appearance. If the temperature is too high, overcooking takes place. If it is too low, the evaporation is insufficient and changes are likely to follow in the partially dried material. If it is too dry and too hot, destruction of the cellular structure is practically sure to follow. It is seen, therefore, that modern dehydration means the scientific control and coördination of the three factors of air, temperature, and moisture.

In England and France dehydration has been practiced, and factories are now in operation. The demand for these foods has, however, required large importations from Canada and to a lesser degree from the United States. In fact, it may be stated that this method of food preservation seems destined to be the next big advance in the development of our food industries.

ADVANTAGES OF DEHYDRATION

The advantages of dehydration are almost too obvious to require extended statement. Most evident of all is the loss in weight. All the vegetables in common use contain from 65 to 95 per cent of water. The dehydrated product made from these vegetables should contain from 5 to 10 per cent of water. There is, therefore, a very large reduction in weight and consequent saving in the transportation charges, which in general are based upon weight.

Similarly, there is a loss in bulk amounting to from 50 to 80 per cent of that of the raw material. The importance of these factors to railroads in times of congestion such as we have just passed through, or to ships in overseas service, is very evident. In sending food to our armies abroad, one ship could easily carry the vegetable requirements which in the green or fresh state would take from ten to twenty-five ships.

From the standpoint of agriculture the greatest advantage of dehydration undoubtedly appears in the stabilization of crops and the conservation of materials. Under the present conditions we are confronted by either a feast or a famine. If we consider potatoes as the most typical root crop, it is a matter of experience that a year in which we get a very large harvest and consequently low prices is likely to be followed by a lean year with a small crop and high prices. This pendulum swing goes on decade after

decade. With dehydration the excess of the years of great yield can be stored up and made available in the following years when prices are higher and the crop much smaller. After a short time this would tend to equalize the amount of planting, and, other things being equal, to give us year by year a sufficient quantity of food materials at normal prices.

The second great advantage is in the conservation of food materials. It is estimated that over 50 per cent of the fruits and vegetables grown in this country now never reach the consumer, as a result of poor transportation facilities, irregularities in marketing, or other causes. By making use of the process of dehydration, the second-quality materials could be preserved by drying, and made available for human food. For example, potatoes of class 2 and 3 (culls) could be used for the manufacture of dehydrated potato and potato flour, a product which has not yet received in this country the attention which it deserves, but which is now being manufactured to some extent in a number of different parts of the country.

A third factor of importance in the relation of dehydration to agriculture lies in the fact that a better diversity of crops can be secured, and as a result of this there will be a good variety of the vegetables which are the equivalent of fresh materials available to poor and rich throughout the year. This means better feeding for the people at large, an evening up of prices, and the prevention of famine or great food shortage as a result of poor crops in any particular location.

The general advantages of this method of treatment for vegetables and fruits maybe summarized as follows:

a. Possibility of utilizing much food now wasted owing to low prices at time of production or difficulty in marketing;
b. The plants for treatment can be located at centers of production and dehydration carried on while the food material is in prime condition;
c. Saving in cost of transportation in dehydrated form due to less weight and bulk;
d. Increased keeping qualities;
e. Nutritional values fully conserved;
f. No loss by crushing or spoilage;
g. Uniformity of quality;
h. Saving in cold storage charges;
i. Saving in tonnage for overseas and transcontinental shipment;
j. Foods require only soaking before cooking;
k. Surplus of one season or locality made available at another time or place.

From the standpoint of army subsistence these general advantages imply:

a. Lower cost of actual food units;
b. Lower cost of transportation;
c. Guaranteed keeping quality;
d. No loss by freezing or spoilage;
e. Saving in storage;
f. Wider range of vegetable foods and consequently
g. Generally improved diet.

While experiments on the best conditions for storage and packing are still being carried on, it is known that these products will retain their good qualities for long periods and under widely different conditions, and that when properly prepared they have the appearance and flavor of fresh materials to a marked degree.

They also seem to possess the essential special properties of substances which render fresh vegetable foods so desirable as antiscorbutics and growth promoters. Trials on both large and small scale at hospitals, training camps and in hotels have led to the conclusion that these foods are especially satisfactory in these practical tests although comment on all has generally been favorable. Distinctly satisfactory reports have been received from the Walter Reed Hospital where at the suggestion of the Food Division, the vegetables were served in the hospital mess and the officers' mess, and from the Medical Officers' Training Camp, Fort Oglethorpe, where the soup mixture was issued for a week or ten days without the knowledge of the consumers, and the verdict was unanimous that the soup during this period was superior to that served hitherto.

The disadvantages in the use of these materials are few and of minor importance. The principal one seems to be that a rather prolonged soaking previous to cooking is necessary for the best results and that slightly longer cooking than with fresh vegetables is required. An intelligent cook quickly learns the treatment essential to ensure the fresh flavor and palatableness which are attainable by proper handling.

REDUCTION IN WEIGHT AND BULK OF VEGETABLES UPON DRYING

The actual reduction in weight obviously depends on the degree of dehydration effected. The following figures have been ob-

tained from a variety of sources and are reasonably reliable although they have not been checked by our own analyses:

String beans	10.4	lbs.	fresh	produce	1 lb.	dried.
Spinach	13.3	"	"	"	"	"
Sweet potato	4.6	"	"	"	"	"
Beets	7.1	"	"	"	"	"
Onions	11.4	"	"	"	"	"
Cabbage	12.0	"	"	"	"	"
Turnips	8.8	"	"	"	"	"
Tomatoes	13.3	"	"	"	"	"
Carrots	6.6	"	"	"	"	"
Potatoes	4.4	"	"	"	"	"

If dried to a moisture content of 8 per cent the following approximate weights of dried material should be obtained per ton of fresh material:

Beans, green	250	lbs.
Cabbage	215	"
Carrots	292	"
Corn (green)	465	"
Lettuce	114	"
Peas (green)	350	"
Potato, white	450	"
Potato, sweet	513	"
Spinach	166	"
Tomatoes	125	"
Turnips	225	"

Data on the reduction in bulk are less easily obtained, and vary greatly since the products are more or less subject to compression in packing. The importance of this will be later mentioned. A few figures are quoted:

String beans	reduced	to	$\frac{1}{5}$	original	volume.
Spinach	"	"	"	"	"
Onions	"	"	$\frac{1}{8}$	"	"
Tomatoes	"	"	$\frac{1}{15}$	"	"
Beets	"	"	$\frac{1}{10}$	"	"
Potato, white	"	"	$\frac{1}{2}-\frac{1}{3}$	"	"
Potato, sweet	"	"	$\frac{1}{2}$	"	"

A more definite unit of measurement for these dried foods is the weight per cubic foot. Expressed in this way the figures are not always in exact agreement owing to differences in the percentage of water. As representative of the product in general,

the following figures are given, the material being loosely packed in cartons or barrels:

Bentz Product	Lbs. per cubic foot
Potatoes	24
Carrots	18.7
Turnips	19
Cabbage	11
Onions	11
Soup mixture	20
Horst Product	
Potatoes	14–15
Onion, steamed	9.75
Turnips, steamed	10–11.6
Turnips, unsteamed	9
Brussels sprouts	10
Carrots, unsteamed	15
Carrots, steamed	15.75
Cabbage	8.25
Beans, white, partly cooked	26.25
Soup mixture	15

An examination of several different makes of dried potatoes, prepared in a number of forms, has given me the following results:

Maker	Form	Lbs. per cubic foot
Dominion	Sliced	21
Chilliwack	Shredded	20.4
Pitcher	Sliced	18.3
Pitcher	Granulated	25.8
Bentz	Cubes	24
Horst	Quartered	16

The practical importance of this matter lies in the fact that in the loosely packed form the weight per shipping ton of 40 cubic feet is relatively low, and while a considerable saving in freight charges is to be secured by sending the dried rather than the fresh or canned material, it seems possible to make a still further saving in this respect.

The following figures express the weights of dried material per shipping ton (40 cu. ft.):

String beans	409	lbs.	equal	to	about	4,000	lbs.	fresh	material.
Spinach	125	"	"	"	"	1,650	"	"	"
Onions	400–450	"	"	"	"	4,000	"	"	"
Turnips	760	"	"	"	"	7,000	"	"	"
Carrots	481	"	"	"	"	3,500	"	"	"

Cabbage	265	lbs.	equal	to	about	4,200	lbs.	fresh	material.
Potato, slices	700	"	"	"	"	3,000	"	"	"
Potato, cubes	960	"	"	"	"	4,000	"	"	"
Potato, granulated	1,025	"	"	"	"	4,200	"	"	"
Potato, sweet	640	"	"	"	"	2,950	"	"	"

Modifications in the process of manufacture are practicable by which many of the vegetables may be prepared in compressed form and in this condition have approximately the same specific gravity as water or slightly higher. The advantage of this procedure is evident from the shipping standpoint as it not only reduces the bulk very greatly, bringing the material to a very satisfactory density for shipment, but it brings about a still further saving in containers, packing, etc.

NUTRITIVE VALUE OF DEHYDRATED FOODS

Since nothing but replaceable water has been removed from the foods, they contain all the food combinations and food values of the original materials. It is not, however, suggested that those dehydrated products should take the place of fresh vegetables when the latter can be secured in plentiful amounts and prime condition at reasonable prices. On the other hand, they are entirely superior to old, heated or wilted vegetables or those which have undergone deterioration by freezing or action of fungi or bacteria, and their advantages from this standpoint need no further argument.

A few analyses of dehydrated vegetables are appended in order to show that the foods are still normal in character and food value and to demonstrate the great saving in weight and bulk due to loss of water.

These analyses agree fairly closely with the theoretical figures calculated from the average analyses given by Atwater and Bryant. Some variation in analyses is expected owing to actual differences in composition with different varieties of vegetable and types of soil.

Some calculated analyses based on a 10 per cent water content are here given for comparison. Especial attention is called to the actual fuel value per pound and the rate of fuel value in the fresh and the dehydrated product. While these are calculated rather than actually obtained by analysis, they nevertheless

ANALYTICAL DATA ON DRIED VEGETABLES

	Lab. number	% Moisture	% Ash	% Protein	% Crude fiber	% Ether extract	% Carbohydrate (by diff.)	Cal. 100 gms.	Cal. 1 lb.
Onions	1	5.61	4.10	12.25	5.06	1.76	68.22		
	8	6.97	3.42	13.12	4.96	.72	70.81		
	3038	5.36	3.25	11.37	3.81	1.23	74.98		
Average		5.98	3.59	13.25	4.58	1.24	71.34	358	1625
Av. Mois. Free			3.82	14.10	4.87	1.32	75.89	381	1729
Turnips	9	3.96	9.43	12.93	9.55	.78	63.35		
	3052	5.79	7.23	16.58	8.04	.25	62.11		
	3040	9.73	5.94	9.00	8.41	.47	66.45		
Average		6.49	7.53	12.84	8.67	.50	63.97	320	1449
Av. Mois. Free			8.05	13.73	9.27	.53	68.42	342	1550
Carrots	3	1.71	4.53	5.26	8.72	2.17	77.61		
	6	5.44	6.07	5.87	8.25	1.24	73.13		
	3037	6.93	5.87	5.17	7.31	1.03	73.69		
Average		4.69	5.49	5.43	8.10	1.48	74.81	343	1554
Av. Mois. Free			5.76	5.70	8.51	1.55	78.48	360	1631
Potatoes	2	7.90	3.89	9.72	1.83	.21	76.45		
	7	5.84	3.88	9.18	1.77	..	79.33		
	3061	4.01	3.52	10.00	1.78	.14	80.55		
Average		5.92	3.76	9.63	1.79	.12	78.78	364	1649
Av. Mois. Free			4.00	10.24	1.90	.13	83.73	386	1753
Cabbage	10	4.44	6.98	19.18	8.27	.97	60.16		
	3045B	4.26	5.62	12.44	7.83	1.03	68.82		
	3046	5.20	5.61	13.56	8.11	1.28	66.24		
Average		4.63	6.07	15.06	8.07	1.09	65.08	339	1536
Av. Mois. Free			6.37	15.79	8.47	1.14	68.23	355	1610
Tomatoes	4	5.17	5.57	17.25	7.28	3.35	61.38		
	11	4.02	8.66	14.18	8.51	1.71	62.92		
Average		4.59	7.12	15.71	7.90	2.53	62.15	343	1555
Av. Mois. Free			7.46	16.47	8.28	2.65	65.14	359	1629
Parsnips	5	2.81	6.40	10.00	6.73	1.77	72.29	354	1605
Mois. Free			6.59	10.29	6.92	1.82	74.38	364	1651

show the general values for dehydrated foods which are entirely practicable from the manufacturing point of view:

Vegetable	% Water	% Protein	% Fat	% Total carboh.	% Fibre	% Ash	Fuel value per lb.	Ratio of fuel value
Beets, fresh, edible portion	87.5	1.6	0.1	9.7	0.9	1.1	215	1: 7.2
Beets, dried	10.0	11.5	0.7	69.8	6.5	7.9	1547	
Cabbage, fresh, edible portion	91.5	1.6	0.3	5.6	1.1	1.0	145	1: 10.6
Cabbage, dried	10.0	16.9	3.2	59.3	11.6	10.6	1536	
Carrots, fresh, edible portion	88.2	1.1	0.4	9.3	1.1	1.0	210	1: 7.6
Carrots, dried	10.0	6.4	3.1	71.0	8.4	7.6	1602	
Celery, fresh, edible portion	94.5	1.1	0.1	3.3	..	1.0	885	1: 15.2
Celery, dried	10.0	18.0	1.6	54.0	..	16.4	1391	
Corn, green, edible portion	75.4	3.1	1.1	19.7	0.5	0.7	470	1: 3.7
Corn, dried	10.0	11.3	4.0	72.1	1.8	2.6	1720	
Cucumbers, edible portion	95.4	0.8	0.2	3.1	0.7	0.5	60	1: 19.5
Cucumbers, dried	10.0	15.6	3.9	60.6	13.6	9.8	1563	
Eggplant, fresh, edible portion	92.9	1.2	0.3	5.1	0.8	0.5	130	1: 12.7
Eggplant, dried	10.0	15.2	3.8	64.6	10.1	6.3	1647	
Lettuce, fresh, edible portion	94.7	1.2	0.3	2.9	0.7	0.9	90	1: 17.0
Lettuce, dried	10.0	20.4	5.1	49.2	11.9	15.3	1528	
Okra, fresh, edible portion	90.2	1.6	0.2	7.4	3.4	0.6	175	1: 9.2
Okra, dried	10.0	14.7	1.6	67.9	31.2	5.5	1607	
Onions, fresh, edible portion	87.6	1.6	0.3	9.9	0.8	0.6	225	1: 7.3
Onions, dried	10.0	11.6	2.2	71.9	5.8	4.4	1634	
Parsnips, fresh, edible portion	83.0	1.6	0.5	13.5	2.5	1.4	300	1: 5.3
Parsnips, dried	10.0	8.5	2.6	71.4	13.2	7.4	1587	
Peas, green, edible portion	74.6	7.0	0.5	16.9	1.7	1.0	465	1: 3.5
Peas, dried	10.0	24.8	1.8	59.8	6.0	3.5	1646	
Potatoes, fresh, edible portion	78.3	2.2	0.1	18.4	0.4	1.0	385	1: 4.1
Potatoes, dried	10.0	9.1	0.4	76.4	1.7	4.2	1598	
Potatoes, evaporated, as purchased	7.1	8.5	0.4	80.9	..	3.1	1680	
Pumpkins, fresh, edible portion	93.1	1.0	0.1	5.2	1.2	0.6	120	1: 13.0
Pumpkins, dried	10.0	13.0	1.3	67.8	15.6	7.8	1565	
Spinach, fresh, as purchased	92.3	2.1	0.3	3.2	0.9	2.1	110	1: 11.7
Spinach, dried	10.0	24.5	3.5	37.4	10.5	24.5	1286	
Squash, fresh, edible portion	88.3	1.4	0.5	9.0	0.8	0.8	215	1: 7.7
Squash, dried	10.0	10.8	3.8	69.2	6.2	6.2	1653	
Tomatoes, fresh, as purchased	94.3	0.9	0.4	3.9	0.6	0.5	105	1: 15.8
Tomatoes, dried	10.0	14.2	6.3	61.6	9.5	7.9	1658	
Turnips, fresh, edible portion	89.6	1.3	0.2	8.1	1.3	0.8	185	1: 8.7
Turnips, dried	10.0	11.2	1.7	70.1	11.2	6.9	1600	
OTHER PRODUCTS FOR COMPARISON—O. E. S. Bul. 28, Revised								
Potatoes, sweet, fresh, edible portion	69.0	1.8	0.7	27.4	1.3	1.1	570	
Potatoes, sweet, dried	10.0	5.22	2.03	79.5	3.8	3.2	1653	

The keeping qualities of these materials is limited only by the lack of observance of care in preparation and storage. Moisture is necessary for the development of molds and bacteria, the great agencies of food deterioration, and so long as the foods are well dehydrated and have been kept so that no moisture is absorbed, they seem to keep in good condition. The most striking illustration of the keeping quality of dried vegetables is the reported saving of some 30,000 pounds of material dried for the British Forces during the Boer War until the outbreak of the present war in 1914, when the vegetables were used with satisfaction in the English army.

The food preparations made by the various methods have shown considerable variation in character and appearance. Differences in the rate of water absorption and the appearance of the pieces after swelling are noted. Aside from these physical differences, it is worth while to consider the sanitary aspect. In most cases there is a partial but probably not complete sterilization. In the mechanical processes much handling is eliminated, so that objections arising from that source are circumvented.

An extensive investigation of the keeping quality under different conditions of storage and different types of containers has been made under the writer's direction. This has shown that with good products in suitable containers there is no deterioration even when the foods are stored for months under the most adverse conditions of temperature and moisture. Without doubt this phase of the problem will be adequately met as the industry develops.

COMPARISON WITH CANNED VEGETABLES

A practical question at once arises as to the comparative utility of dehydrated and canned vegetables. The answer to this question requires consideration not merely of food values and availability, but also of relative cost of manufacture, relative cost of tin cans and packing cases, and relative cost of transportation. The cost of raw material alone would be essentially the same.

Vegetables may be conveniently grouped into two classes: (1) Those ordinarily canned, but also dried successfully, including peas, string beans, lima beans, tomatoes, beets, corn, pumpkin, spinach, cabbage, and sweet potato. (2) Those rarely or never

canned, but well adapted to drying, as potatoes, turnips, carrots, parsnips, celery, onions, and sprouts.

Comparisons should be made, therefore, only with the vegetables of class 1. These products are now canned in enormous quantities annually as shown by the following figures for 1917, which have been supplied to me as advance information from official sources:

	Cases		Cans
Tomatoes	15,076,074	=	361,825,776
Corn	10,802,952	=	259,270,848
Beans (all kinds)	4,486,070	=	107,665,080
Beets	739,565	=	17,749,560
Spinach	332,305	=	7,975,320
Squash and pumpkin	1,065,483	=	25,571,592
Sweet potato	238,250	=	5,718,000
Cabbage and kraut	1,493,122	=	35,834,928
Peas	9,829,153	=	236,899,672
Apples, apricots, peaches, pears	6,725,568	=	161,413,632

Since each individual can requires the use of from five to seven ounces of tin plate for the container, the saving in expense from this source alone is enormous. A less, but still noteworthy saving, would also be effected in packing cases. The third great advantage is in the transportation charges. Since the canned foods never contain less water than the fresh food and frequently contain an even higher percentage, it is seen that an undue proportion of the expense of canned goods lies in the handling, canning, and transportation of water.

The following table shows the weight of food as prepared for the can, the number of cans, size of can, number of cases, and weight and volume when prepared for shipment of some of the leading lines of canned goods:

WEIGHT AND BULK OF ONE TON OF VARIOUS VEGETABLES WHEN CANNED

Vegetable	Weight prepared	No. cans	Size	No. cases	Cu. ft. ready to ship	Total weight ready to ship
Corn	750 lbs.	740	2	31	31.77	1426 lbs.
Peas	1960 "	2240	2	93.3	95.63	4291 "
String beans	1500 "	2000	2	83.3	85.38	3832 "
Lima beans	800 "	1200	2	50	51.25	2300 "
Tomatoes	1100 "	535	3	22⅓	38.41	1763 "
Pumpkin	1400 "	700	3	29	49.88	2146 "
Sweet potatoes	1450 "	720	3	30	51.60	2250 "
Cabbage	1450 "	800	3	33	56.76	2400 "
Sliced vegetables	1600 "	267	10	45	55.80	2700 "

Reference to the table on page 60 of this report shows the weights of dried products of these same vegetables to be per ton:

Corn	465 lbs.	
Peas	350 "	
String beans	200 "	about
Green beans	250 "	
Tomatoes	125 "	
Pumpkin	200 "	
Sweet potato	513 "	
Cabbage	215 "	

A recent report on an analysis of dried tomatoes for moisture and solids, brought out the statement that one pound of the product with a water content of 7.4 per cent was equivalent to 10½ two-pound cans of solid pack Del Monte Brand tomatoes containing 5.02 per cent solids.

The saving to be effected by use of dried products is indicated by the estimated cost of canned and dried tomatoes shipped from California to France. It is stated that a case of canned tomatoes, costing $2.60 in California, costs $7 laid down in Havre. The equivalent amount of dried tomatoes selling 26 cents per pound in California, costs 40.5 cents in France, a saving of $6.595 or 94 per cent. While this is probably the most favorable case that could be cited it is certain that very large savings could be made in every line where dried products can replace canned ones. At the present day the value of the food substance in the can is but a fraction of the cost of labor, containers, packing cases and transportation charges.

COMPARISON OF DRIED AND CANNED FRUITS

What has been said of canned and dried vegetables applies also to fruits. Without discussing the whole problem it may be of interest and value to show the comparison between the dried fruits of the types at present on the markets and the same foods when canned.

YIELD PER TON OF FRUIT

Fruit	Weight prepared for canning	No. cans	Size	Cases	Cu. ft. boxed	Total weight boxed
Apples	1400 lbs.	1066	$2\frac{1}{2}$	44	66	2640
Peaches	1500 "	1143	$2\frac{1}{2}$	$47\frac{5}{8}$	71.25	2850
Apricots	1500 "	1143	$2\frac{1}{2}$	$47\frac{5}{8}$	71.25	2850
Pears	1500 "	1143	$2\frac{1}{2}$	$47\frac{5}{8}$	71.25	2850

Each can of these products contains 21 ounces of fruit and 8 ounces of syrup. The fruit contains on an average more than 85 per cent water. The actual weight of solids in each can is, therefore, small. The dried products are, on the other hand, about 80 per cent solids and 20 per cent water.

On a basis of actual food units (calories) we find, therefore, that the dried fruits have about the following comparative values per ton of fresh material:

	Canned			Dried		
	Weight water	Weight solids	Calories per lb.	Weight water	Weight solids	Calories per lb.
Apples	1184.4	215.6	290	308	1092	1380
Peaches	1321	179	220	285	1215	962
Apricots	1221	279	340	300	1200	1344
Pears	1216	284	355	323.5	1176.5	1180
Prunes	....	...	...	...	....	1430
Raisins	....	...	...	...	....	1534

Comparing weight and bulk when packed for shipment, we have the following figures:

Fruit	Canned		Dried	
	Weight boxed	Volume boxed	Weight boxed	Volume boxed
Apricots	....	71.25	....	37.35
Peaches	....	71.25	....	37.35
Pears	....	71.25	....	37.35

The work in commercial dehydration is still in its early stages in this country. There are many problems yet to be determined. We are now attempting to find out which processes are best adapted for general use, whether dehydrated products are deficient in any of the nutritive principles which they should possess and which the fresh vegetables themselves possess, to work out satisfactory methods of storage and transportation by selecting the best types of containers, and to acquaint the consumer, especially in the cities, with the great advantages which are likely to be gained by the use of dehydrated products.

Obviously, dehydration will succeed commercially only in those regions with abundant crops which can be contracted for at planting for a guaranteed price, or in centers having a short haul from the point of production and suitable shipping facilities. If, however, the problem is met scientifically there appears no reason to doubt that a demand will be created and that dehydration will become, as canning has, a great industry of immense importance to agriculture, with the further advantage that no tin plate will be required and that the consumer will purchase practically nothing but food material, whereas in the purchase of canned goods he is buying and the railroads are shipping enormous quantities of water.

In order to insure a successful industry, dehydrated products must have the quality which will make them the practical equivalent of the fresh materials. They must be handled in a sanitary manner, be put up in suitable packages, and sold at a price which will make them throughout the year comparable with fresh vegetables. We believe this can be done, and that dehydration will become the servant of agriculture as well as of the dwellers in the great cities.